Maritime Technology and Society
Vol. 2(1): 16-21, February 2023
https://doi.org/10.62012/mp.v2i1.25478

# Impact of Axe Bow Hull Shape on Patrol Ship Resistance, Freeboard, and Trim

**[*]Suardi [1], Taufik Hidayat [1], Mohammad Bagus Firmansyah [1], and Aung Ye Kyaw [2]**

[1]Naval Architecture Program of Kalimantan Institute of Technology, Indonesia
[2]Department of Marine Administration, Ministry of Transport and Communications, Myanmar
[*]Correspondence author: suardi@lecturer.itk.ac.id; Tel.: 085244317201
Received 01 January 2023; Received in revised form 9 January 2023; Accepted February 2023

**Abstract**

Patrol Ship is a ship that prioritizes speed because it secures water areas. This study uses patrol ship design as the object of study in determining the amount of ship resistance because this ship uses an axbow hull form. This research aims to assess the effect of the Axe Bow type hull form on ship resistance, freeboard, and ship trim. The method used in this study is a simulation method with the help of maxsurf software. The results of this study indicate that using the Ax Bow Hull Shape model gives a resistance value of 245.9 kN with a speed of 25 knots, a freeboard value of 0.95, and a trim of 0.006575 m and is included inthe "Accepted" category. With these results, the axe bow model for patrol ships can be used as an alternative in selecting the hull shape of a fast ship.

**Keywords:** Patrol Ship; Axe Bow Hull Shape; Resistance; Freeboard; Trim

## 1. Introduction

A patrol ship is one of the ships that fall into the category of water guard ships. The primary function of this ship is to guard an area of territorial and coastal waters against violations of the lawthere [1]. Patrol ships generally belong to government agencies that aim to carry out water surveillance duties and chase ships that violate the rules in a country's territorial waters [2]. Its function, ship patrol, is also equipped with types of weapons to guard a country's territory against security disturbances such as pirates and infiltration of other countries [3]. Many territorial violations have occurred in Indonesia, ranging from illegal fishing to piracy, all because patrol boats cannot still oversee and guard the area [4]. Because ship patrol is crucial for a country, ship patrol is essential for a country whose territory is dominated by waters, such as Indonesia [5].

The advantage of ship patrol is its good maneuverability and high speed. In general, ship designs have limited rates. Then ship patrol must have high speed to support its operations at sea [6]. For example, the Natuna region, which has a water area of 222,683.74 km2, has a high potential for capturing fisheries resources, making it a Fisheries Management Area (WPP 711) prone to criminal activities such as illegal fishing [7]. WPP 711 is sea waters bordering several ASEAN countries such as Indonesia, Singapore, Malaysia, Vietnam, and China. Several studies related to shipping design have also been carried out, such as the design of a 70 GT fishing vessel [8], the ship power plan layout for the electricity needs of the Kagean area [9], and the ship patrol design made to be able to operate in the Natuna area [3]. All the ship design processes begin with the primary dimension planning process until the general arrangement is made, but there is still a lack of in-depth study for studies related to the ship's hull shape.

Ship speed becomes a problem in the ship design process. Each type of ship must have a different speed variation [10]. Fast ship types, such

E-ISSN: 2828-6669; P-ISSN: 2828-7010

as patrol ships, must thoroughly study the hull shape to reduce the resulting ship resistance. The more excellent the resistance will require considerable propulsion engine power to make the ship capable of sailing at the desired speed. Research on engine power testing shows that increasing engine power will cause fuel consumption to increase [11]. Several studies have been carried out on optimizing the hull shape of ships, such asbulbous bow shape variations [12] and bow variations on icebreakers [13] which produce lower resistance values with modifications. One form of improvement of the hull shape is to use the type of ax bow hull shape, which with this model, makes the hull sharper at the bow to reduce the resistance of the ship.

The following parameters to pay attention to are freeboard correction and trim. It is also important because the ship's maneuvers must remain stable with safe freeboard and trim conditions. Freeboard aims to maintain the safety of passengers, crew, cargo, and the ship. If the ship has a high freeboard, the reserve buoyancy will be significant, so the ship has residual buoyancy if damaged [14]. Meanwhile, the trim is made for an even keel because an extensive trim will affect the ship's maneuverability [15]. By looking at the background above, this study hypothesizes if the hull shape on the patrol ship can provide optimal speed for the ship.

## 2. Materials and Methods

This research is developing research on patrol ship design to guard Natuna Sea, which will be proven by the hull shape ax bow improving the shipping speed. This ship is designed and has an axe bow-type hull shape making it suitable for further in-depth research. The resistance testing process is carried out using maxsurf resistance software. Here are the main dimensions of the designed ship [3] Length Overall (LOA) is 50.2 m, Breadth (B) is 9.32 m, Depth (H) is 4.45 m, Draft (T) is 3.50 m, and Ship Velocity (Vs) is 25 Kn. From the primary dimension of the ship above, further design testing will be carried out on maxsurf resistance to obtain the total resistance value of the ship

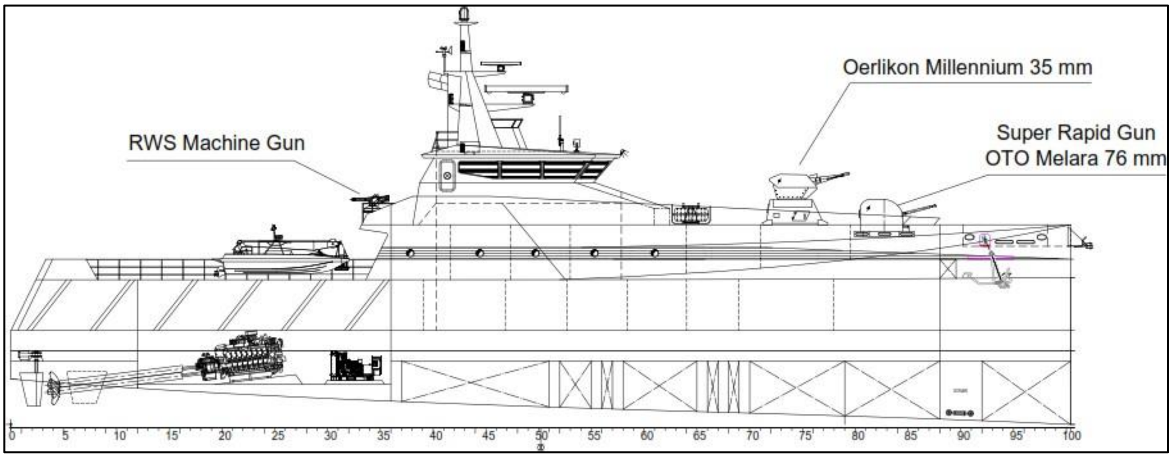


**Fig.1**. General Arrangement Patrol Ship Design (Side View) [3]


**Fig.2.** 3D Patrol Ship Design [3]

E-ISSN: 2828-6669; P-ISSN: 2828-7010

## 3. Results

### 3.1 Ship Coefficient Calculation

From the Froud Number value obtained, calculate the ship's coefficients. The ship coefficients referred to include the Block coefficient (Cb) is 0.391, the midship coefficient (Cm) is 0.729, the waterplane coefficient (Cwp) is 0.805, the prismatic coefficient (Cp) is 0.536, the volume displacement (∇) is 564.73 $m^3$, and displacement (Δ) is 578.8 ton [13].

### 3.2 Resistance Calculation

The total ship resistance is calculated to get the engine power the ship needs. Thus the ship can sail at the desired speed. Several things affect the ship's resistance, such as the size of the ship. The hull's shape below the waterline and the required rate of the ship. To calculate the drag of the ship, the Holtrop method is used. For the value of the ship's fraud number (Fn) that is designed to enter the displacement phase range, namely Fn = 0.579 ($0.0 < Fn < 0.6$)

The analysis is assisted by using Maxsurf Resistance software. Before carrying out a resistance analysis using the Holtrop method, several ship dimensions need to be rechecked so that these values meet the requirements for calculating Holtrop on Maxsurf Resistance.

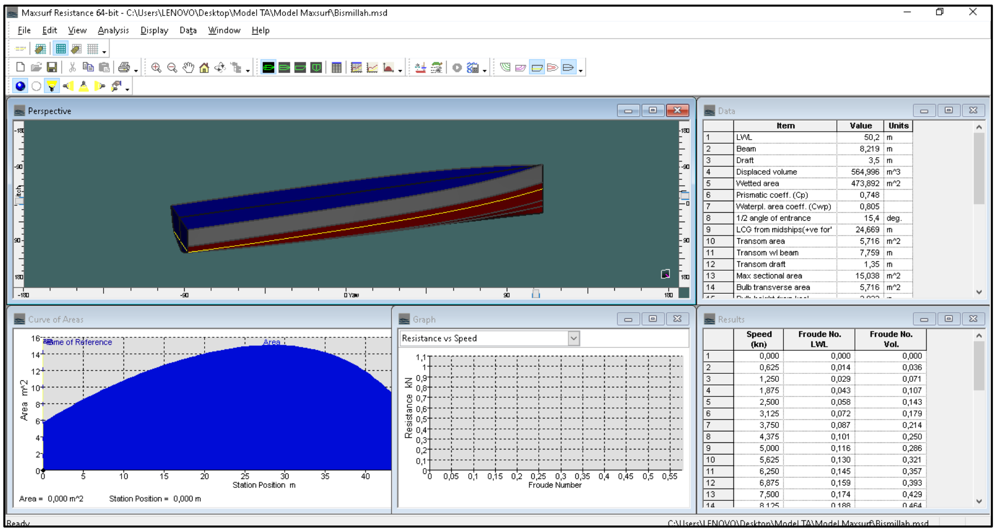


**Fig.3.** Initial display of maxsurf resistance

**Table 1.** Ship resistance for each speed variation

| No. | Speed (Knot) | Froude No LWL | Froude No Vol | Holtrop Resist (kN) | Holtrop Power (kW) |
|---|---|---|---|---|---|
| 9 | 5,000 | 0,116 | 0,286 | 0 | 0 |
| 10 | 5,625 | 0,130 | 0,321 | 0 | 0 |
| 11 | 6,250 | 0,145 | 0,357 | 26,9 | 86,614 |
| 12 | 6,875 | 0,159 | 0,393 | 25,5 | 90,078 |
| 13 | 7,500 | 0,174 | 0,429 | 26,5 | 102,378 |
| 14 | 8,125 | 0,188 | 0,464 | 28,5 | 119,241 |
| 15 | 8,750 | 0,203 | 0,500 | 31,1 | 139,949 |
| 16 | 9,375 | 0,217 | 0,536 | 34,1 | 164,478 |
| 17 | 10,000 | 0,232 | 0,571 | 37,6 | 193,216 |
| 18 | 10,625 | 0,246 | 0,607 | 41,4 | 226,547 |
| 19 | 11,250 | 0,261 | 0,643 | 45,6 | 263,817 |
| 20 | 11,875 | 0,275 | 0,678 | 50,2 | 306,654 |
| 21 | 12,500 | 0,290 | 0,714 | 55,8 | 359,131 |
| 22 | 13,125 | 0,304 | 0,750 | 62,5 | 422,193 |
| 23 | 13,750 | 0,319 | 0,786 | 69,2 | 489,671 |
| 24 | 14,375 | 0,333 | 0,821 | 74,9 | 554,089 |
| 25 | 15,000 | 0,348 | 0,857 | 79,8 | 615,601 |

E-ISSN: 2828-6669; P-ISSN: 2828-7010

| No. | Speed (Knot) | Froude No LWL | Froude No Vol | Holtrop Resist (kN) | Holtrop Power (kW) |
|---|---|---|---|---|---|
| 26 | 15,625 | 0,362 | 0,893 | 84,7 | 680,650 |
| 27 | 16,250 | 0,377 | 0,928 | 90,5 | 756,515 |
| 28 | 16,875 | 0,391 | 0,964 | 97,9 | 849,620 |
| 29 | 17,500 | 0,406 | 1,000 | 107,8 | 970,874 |
| 30 | 18,125 | 0,420 | 1,036 | 119,3 | 1112,553 |
| 31 | 18,750 | 0,435 | 1,071 | 130,8 | 1261,599 |
| 32 | 19,375 | 0,449 | 1,107 | 142,3 | 1417,920 |
| 33 | 20,000 | 0,464 | 1,143 | 153,7 | 1581,410 |
| 34 | 20,625 | 0,478 | 1,178 | 165,1 | 1751,953 |
| 35 | 21,250 | 0,493 | 1,214 | 176,5 | 1929,422 |
| 36 | 21,875 | 0,507 | 1,250 | 187,8 | 2113,680 |
| 37 | 22,500 | 0,522 | 1,286 | 199,1 | 2304,576 |
| 38 | 23,125 | 0,536 | 1,321 | 210,3 | 2501,950 |
| 39 | 23,750 | 0,551 | 1,357 | 221,5 | 2706,905 |
| 40 | 24,375 | 0,565 | 1,393 | 234,3 | 2938,285 |
| 41 | 25,000 | 0,580 | 1,428 | 245,9 | 3162,959 |

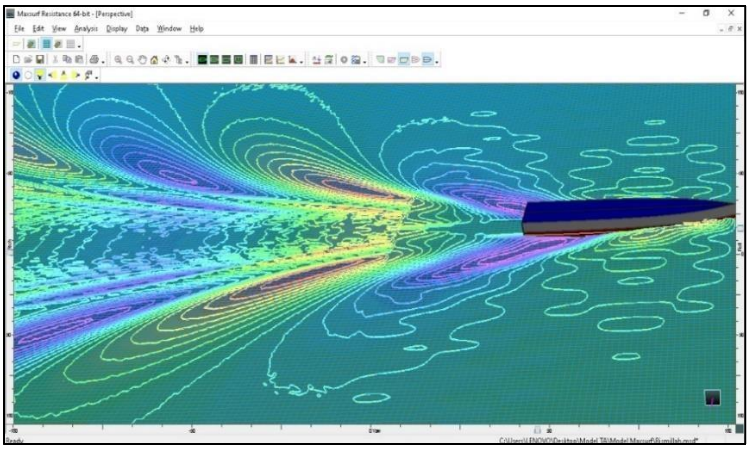

**Fig.4.** Resistance Running Results

From the picture above, the value of the ship's resistance at a speed of 25 knots is 245.9 kN, and the required engine power is 3162,959 kW plus a margin of 15% so that the engine power is 3637,403 kW. Because the ship to be designed uses two engines, the emphasis is divided into 2 with a final output of 1818,701 kW.

3.2 Freeboard Correction

The types of ships are divided into two: type A ships and type B ships. Type B ships are ships other than type A, while Type A ships are; ships designed to lift bulk cargo, ships with high stability on open decks, and ships with a high level of safety against flooding.

This research ship is included in the category B type ship with a standard size of Fb1 = 455 mm(for L = 51 m), then corrections are made.

a. Freeboard correction to block coefficient (Cb)

CB correction was only made for ships with Cb > 0.68. The Cb of this research ship was <0.68, so no correction was needed.

b. Freeboard correction with a length < 100 m

For ships with LPP <100 m, the correction is as follows:

Fb2 = 7.5 x (100-L) (0,35-E/L) [mm]

= 112.8684 mm

c. Freeboard corrections arise with the height of the ship. For ships with a price of D > L/15, it is corrected as follows:

Fb3 = R(D-L/15) [mm] (2)

R = L/0.48 (for L<120 m)

= 104.58

Fb3 = 115.39 mm

E-ISSN: 2828-6669; P-ISSN: 2828-7010

Freeboard Total is :
FB' = $Fb_1$ + Fb2 + Fb3 (3)
= 0.68 m

The size of the freeboard is obtained from the ship's H-T, thenH-T = 0.95

So, the correction value from the Freeboard calculation refers to the Non-Convention Vessel Rules. Standard Indonesia Flagged Chapter VI in the following table :

**Table 2.** Freeboard correction

| Explanation | Value |
|---|---|
| Required freeboards | 0.68 |
| Real freeboard | 0.95 |
| Conclusion | Accepted |

3.3 Trim Calculation

Trim can be defined as a ship with no even keel conditions. Trim can occur due to uneven load on the vessel, which is gravity with a static moment. Trim can be divided into two, namely, the stern trim and also the bow trim. The occurrence of stern trim can be said if the bow draft is lower

than the draft at the stern. Vice versa for a trim bow.

Trim = ((LCG-LCB). LPP) / GML) (4)
= 0.006575 m

Trim Condition = Stern Trim (due to the trim value > 0)

Trim limit = (LCG-LCB) (5)

= 0.014
Requirements as per SOLAS Regulation 2000 Chapter 11-1 is 0.0502. The total Condition was Accepted (LCG-LCB < 0.1% Lwl).

## 4. Conclusions

The results showed that using the hull shape ax bow, the resistance value for the patrol ship was 245.9 kN at a speed of 25 knots. The freeboard value also complies with a value of 0.95. A trim of 0.006575 m and a trim limit of 0.014 to accept the total condition. It has met the requirements for a patrol ship because it can be said that this design is safe with a speed value that meets fast boats and freeboard and trims values included in the excellent category.

**References**

[1] A. Lajeunesse, "Canada's Arctic Offshore and Patrol Ships (AOPS): Their history and purpose," *Mar. Policy*, vol. 124, no. December 2020,
[2] "Offshore Patrol Vessels - Damen." https://www.damen.com/vessels/defence-and-security/opv (accessed Feb. 16, 2023).
[3] A. I. W. Suardi and T. H. Muhammad Uswah Pawara, "Patrol Ship Design to Guard the Natuna Seas," vol. 7, no. 3, pp. 171–179, 2022.
[4] B. Ivan, "Illegal Fishing Di Kawasan Perairan Kepulauan Bangka Belitung (Studi Kasus Penangkapan Ikan Tanpa Dokumen Yang Sesuai)," J. Kriminologi Indones., vol. 10, no. 2, pp. 41–48, 2014.
[5] B. Le Roy, C. Aufauvre-Poupon, A. Ferragu, A. Vannier, C. Martin-Krumm, and M. Trousselard, "Cardiac biosignal in confined nuclear submarine patrol: Heart rate variability a marker of adaptation," Acta Astronaut., vol. 203, no. June 2022, pp. 469–482,2023.
[6] F. Lestari, A. Adiwibowo, A. Kadir, and N. A. Ramadhan, "Validating the six-year (2016–2021) anthropogenically induced small island wildfire hazards in Pulau Seribu archipelago, Indonesia," Prog. Disaster Sci., vol. 14, no. May, p.100-236,2022.
[7] S. S. Suardi, "Desain Kapal Penangkap Ikan Multipurpose 70 Gt," Inovtek Polbeng, vol. 8, no. 2, p. 175, 2018.
[8] S. Suardi, "Desain Ship Power Plant Sebagai Alternatif Krisis Listrik di Pulau Kagean, Jawa Timur," JST (Jurnal Sains Ter., vol. 6, no. 2, 2020.
[9] X. Tang, M. Zou, Z. Zou, Z. Li, and L. Zou, "A parametric study on the ice resistance of a ship sailing in pack ice based on CFD-DEM method," Ocean Eng., vol. 265, no. September, p. 112563, 2022.
[10] S. S. Suardi, "Analisa Penggunaan Biodiesel Minyak Jagung Sebagai Campuran Bahan Bakar Alternatif Mesin Diesel," Inovtek Polbeng, vol. 9, no. 2, p. 280, 2019.
[11] Y. Zhang, X. Li, S. Ma, W. Shao, and Y. Zhang,

"Numerical investigation on the water entry of bow-flare section with different bulbous bow shapes," Ocean Eng., vol. 257, no. June, p.111715,2022.

[12] I. J. Caecielia and N. D. Tuharea, "Analysis of Hull Shape Art, Speed, Resistance, Power Using Holtrop Method On A Vessel With DWT 12,335 Ton," Marit. Park J. Marit. Technol. Soc., vol. 1, no. June, p. 7010, 2022.

[13] S. Munakata et al., "An investigation into false-negative cases for low-freeboard ships in the vulnerability criteria of dead ship stability," Ocean Eng., vol. 266, no. P5, p. 113130, 2022.

[14] H. Tu, K. Xia, E. Zhao, L. Mu, and J. Sun, "Optimum trim prediction for container ships based on machine learning," Ocean Eng., no. April, p. 111322, 2022.

[15] Manen, J. D., & Oossanen, P. V. Principles of Naval Architecture. In E. V. Lewis, Principles of Naval Architecture Second Revision (p. 154). Jersey City: The Society of Naval Architects and Marine Engineers, 1988.

[16] I. J. Caecielia and N. D. Tuharea, “Analisys of Hull Shape Art, Speed, Resistance, Power Using Holtrop Method On A Vessel With DWT 12,335 Ton,” Marit. Park J. Marit. Technol. Soc., vol. 1, no. June, p. 7010, 2022.

E-ISSN: 2828-6669; P-ISSN: 2828-7010